SSMEM HANDBOOK

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1 INTRODUCTION

The Spatio-Spectral Maximum Entropy Method (SSMEM) is a tool for solar microwave imaging spectroscopy which covers wide frequency range. It has been initially developed by Komm et al.[3] and recently further improved by Bong et al[2]. In this document I briefly describe how to use the current version of SSMEM. Refer to [2] for the philosophy and the scheme of SSMEM. More detailed explanation can be found in [1].

In [1, 2] two optimization algorithms are presented, i.e. conjugate gradient method and Newton-Raphson method. Both techniques reproduced the map and spectra at compatible quality while the speed of convergence to solution is certainly higher when the Newton-Raphson method was used. Therefore I describe only the Newton-Raphson method based SSMEM. The difference between those two with respect to the user interface is quite minor, e.g. used program files, displayed text in the process, and so on.

2 INSTALLATION

The SSMEM is an IDL program and it requires IDL 5.6 or higher, running independently from SolarSoft. Relevant files are as follows:

Doc Documents directory.

- **manual.tex** This document source.
- **manual.ps** This document.

Model Input and output directory.

- **a3.min** Model input file.
- **a3_tru.mou** Model maps.
- **a3_cr.mou** CLEAN maps of the model.
- **mk_mdl_a3.pro** Source for **a3.min** generation.

get_ovsa_uv.pro Subroutine called by **mk_mdl_a3.pro**. Generate OVSA UV distribution.

ovsa_uv.pro Subroutine called by **get_ovsa_uv.pro**.

get_blcor.pro Subroutine called by **ovsa_uv.pro**.

bdots.pro Subroutine called by **ovsa_uv.pro**.

cvd_ellipse.pro Subroutine called by **mk_mdl_a3.pro**. Generate a Gaussian ellipse.

savemou.pro Subroutine called by **mk_mdl_a3.pro**. Save the generated model.

NR Program source directory.

clean.pro CLEAN program.

clean_beam.pro Subroutine of CLEAN.

clean_only.pro Subroutine of CLEAN.

cvd_ellipse.pro Generate a Gaussian ellipse.

fft_uv2xy.pro Calculate dirty map.

fft_xy2uv.pro Calculate visibility.

mem.pro Main program of MEM.

mem_get_input.pro Generate input parameters of MEM.

plot_3maps.pro Show the result in three panels.

plot_vis2vis_simpl.pro Show the result visibility in comparison with the input visibility.

readmin.pro Read input.

readmou.pro Read output.

savemou.pro Write output.

ssmem.pro Main program of SSMEM.

ssmem_chi2chk.pro Check χ^2 of the default map.

ssmem_clean.pro Obtain CLEAN maps for multiple frequencies.

ssmem_control.pro Control box for the progress view.

ssmem_get_input.pro Generate input parameters of SSMEM.

ssmem_grd.pro Calculate the gradient.

ssmem_grd_chi2.pro Calculate the gradient of χ^2.

ssmem_grd_entropy.pro Calculate the gradient of spatial and spectral entropies.

ssmem_maximiz.pro Find the maximum entropy maps.

ssmem_progress.pro Show the progress in 2 by 2 panels.

ssmem_show_uv.pro Show *uv* distribution.

ssmem_uvgrid.pro Average the input visibility data.

ssmem_vsel.pro Select the input data.

ssmem_xyscan.pro Show the map in progress.

3 QUICK START

Start IDL, change the current directory to **NR**, and open **ssmem_get_input.pro**. It begins with something like following:

```
pro ssmem_get_input, vsl, cmap, cln, uv, vis, wgt, nmap, misc, $
 model = mmap, flux = flux, ferr = ferr, spwgt = spwgt, tmin = tmin

    mdldir = '../Model/'
    inp ={inuvfile:mdldir + 'a3.min', $
     tbegstr:'200000',tendstr:'200000', $
     bif:0, eif:39, $
     fif:[-1], $  ;tab added for SSMEM
;     fif:[      1,      3,      5,  6,  7,      9, $
;           10, 11,     13, 14, 15,     17, 18, 19, $
;               21, 22, 23,     25, 26, 27,     29, $
;           30, 31,     33, 34, 35,     37, 38, 39], $
     poln:'R', imsiz:128, $
     niter:2000, clgain:0.02, clstop:2., $
     method:'CLEAN + SSMEM', outfile:'tmp.mou'}
    spwgt = 1.
    cln_restore = mdldir + 'a3_cr.mou'   ;set to restore CLEAN map
;    cln_save = mdldir + 'a3_4h2m_cr.mou'   ;set to save CLEAN map
    trufile = mdldir + 'a3_tru.mou'  ;set to retrieve true map flux
;    model = 'dg_1r.mou' ;set to retrieve default map
;    conv = 1b   ;set to convolve the default map with beam.
```

You can run SSMEM using these parameters by simply typing:

```
IDL>ssmem
```

Set `savefile` keyword to a file name to save the output:

```
IDL>ssmem, savefile = '../Model/a3_1r.mou'
```

The saved file can be read using `readmou`:

```
IDL>mou = readmou('../Model/a3_1r.mou')
```

Currently **ssmem_get_input.pro** generates every input parameters and some optional parameters, i.e. `model`, `flux`, and `spwgt` (See §4). In this file, you can adjust the generated parameters by modifying the beginning section:

- `mdldir` is the path to the input file.
- `inp` structure has the same tags as `imagr` program except `fif` tag. `fif` tag is used to exclude some frequencies from the selected frequency range given by `bif` and `eif`. Set `fif` tag to `[-1]` not to exclude any frequency. The `outfile` tag is ignored in current version of SSMEM. To save the output, use `savefile` keyword in running `ssmem`.

- Setting `cln_save` saves the CLEAN maps returned by **ssmem_clean.pro**. The saved CLEAN maps can be retrieved next time by setting `cln_restore`, skipping CLEAN process.
- Setting `trufile` reads the true model map to calculate `flux`. If not set, `flux` is calculated from CLEAN maps.
- Set `model` to retrieve the default map. If not set, flat maps having calculated `flux` is used. Setting `conv` convolves the default map with the CLEAN beam.

Eventually these processes should be replaced with a proper user interface.

4 FILE FORMATS AND PARAMETERS

The input format for SSMEM is currently ***.min**. It is actually identical to the ***.uv** file except that ***.uv** is an IDL save file. **a3.min** file was saved by **mk_mdl_a3.pro** using codes like the following:

```
cal = {info : info, t : t, f : f, uv : -conj(uv), $
     rr : rr, ll : ll, $
     tp : complex(tpr, tpl), $
     wgt : complex(mdl_wgt_uv, mdl_wgt_uv)}

openw, lun, filename + '.min', /get_lun, /xdr
writeu, lun, nt, nb, nf, na, cal
free_lun, lun
```

You can convert **a3.min** file to **a3.uv** by simply typing:

```
IDL>cal = readmin('a3.min')
IDL>save, cal, filename = 'a3.uv'
```

To use ***.uv** file as an input to SSMEM, the line 67 in **ssmem_vsel.pro**

```
cal = readmin(inp.inuvfile)
```

could be modified to

```
restore, inp.inuvfile
```

The output file saved by setting `savefile` keyword can be read by typing like

```
mou = readmou(filename)
```

`mou` is an anonymous structure tags of which is described in Table 1.

`ssmem` accepts following parameters:

```
ssmem, vsl, cmap, cln, uv, vis, wgt, nmap, misc, $
 model = mmap, flux = flux, ferr = ferr, spwgt=spwgt_, tmin = tmin_, $
 tol = tol_, savefile = sfile, continue = cont_
```

Short descriptions for each parameters are given in Tables 2–4.

Table 1: TAGS OF THE OUTPUT STRUCTURE

Name	Type	Dimension	Description
`f_ghz`	float	Array[nf[a]]	Frequency in GHz.
`tb_xy`	float	Array[nm[b], nm, nf]	Temperature map in MK.
`xyint`	float	Array[nf]	Pixel size in arcsec.
`bmin`	float	Scalar	Minor axis of the CLEAN beam in pixels.
`bmaj`	float	Scalar	Major axis of the CLEAN beam in pixels.
`pa`	float	Scalar	Position angle of the CLEAN beam in degree. Counter clockwise from the y axis.
`alp`	float	Array[nf]	Lagrange multipliers α_k.
`bet`	float	Array[nf]	Lagrange multipliers β_k.

[a]Number of frequencies.
[b]Number of pixels in one direction.

Table 2: SSMEM INPUT PARAMETERS

Name	Type	Dimension	Description
`vsl`	structure	Anonymous	Various information returned by **ssmem_vsel.pro**.
`cmap`	float	Array[nm, nm, nf]	CLEAN map in MK.
`cln`	structure	Anonymous	Various information returned by **clean.pro** with the highest frequency map.
`uv`	complex	Array[nt[a], nb[b], nf]	*uv* coordinate returned by **ssmem_vsel.pro**.
`vis`	complex	Array[nt, nb, nf]	Visibility returned by **ssmem_vsel.pro**.
`wgt`	float	Array[nt, nb, nf]	$1/\sigma^2$ returned by **ssmem_vsel.pro**.

[a]Number of time sequence
[b]Number of baselines

Table 3: SSMEM OUTPUT PARAMETERS

Name	Type	Dimension	Description
`nmap`	float	Array[nm, nm, nf]	SSMEM map in MK.
`misc`	string	Array[7]	Miscellaneous information like the method name, frequencies in GHz, number of iterations, relative χ^2, relative flux, α, and β

Table 4: SSMEM OPTIONAL PARAMETERS

Name	Type	Dimension	Description
`model`	float	Array[nm, nm, nf]	Default map in MK. If not given, `cmap` truncated at `tmin` is used.
`flux`	float	Array[nf]	Flux of each frequency map in sfu. If not given, `model` fluxes are used.
`ferr`	float	Array[nf]	Acceptable flux errors in sfu. If not given, `tol` $\times$ `flux` is used.
`spwgt`	float	Scalar	Weight of the spectral entropy. Default value is 1.
`tmin`	float	Array[nf]	Minimum temperature acceptable in `model` in MK. Dafault values are 0.01.
`tol`	float	Scalar	Small number used in convergence criteria. Default value is 0.03.
`savefile`	string	Scalar	File name to store the result. Saved file can be read using **readmou.pro**.
`continue`	integer	Scalar	Set this keyword to resumed the aborted process. Maps and Lagrange multipliers are restored from `savefile`. Input parameters are assumed to be the same as those of the aborted precess.

References

[1] Bong, S.-C, 2004, Ph.D. thesis, Seoul National Univ.

[2] Bong, S.-C., Lee, J., Gary, D. E., & Yun, H. S. 2004, ApJ, submitted

[3] Komm, R. W., Hurford, G. J., & Gary, D. E. 1997, A&AS, 122, 181